Integrated Fish Farming: A simple, cost-effective technology to ensure employment, food and nutritional security for marginal and small hill farmers

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***Abstract*- Integrated Fish Farming (IFF) is a sustainable and eco-friendly approach that combines fish farming with other agricultural practices, such as poultry farming, mushroom, livestock rearing, crop production and other systems that are mutually supportive. Sequential linkages between different farming activities are established in such a way that the waste from one biological system serves as nutrients for another biological system. Such integration thus ensures optimum utilization of available resources and results in maximum and diversified farm output making IFF a profitable venture. To make farming activities economically viable and ecologically sustainable, several multi-enterprise IFF models relevant to small and marginal hill farmers were developed and evaluated on farmers' fields over the last two decades. Exotic fish; silver carp, grass carp and common carp were stocked at 45:35:25 into the pond, due to their known compatibility with each other, faster growth and resistance to biotic and abiotic stress. Chick birds of a dual-purpose hybrid Kuroiler, a hardy breed of chicken raised for both egg and meat were stocked. Small scale IFF models created in hill region enables the agricultural production system productive, profitable and sustainable. Nutritional requirement of the system is self- sustained through resource recycling. Besides year round employment and substantial monetary gain, the farmer's family got fresh vegetables and good quality animal protein, which has improved nutritional status of the household. Various IFF models evaluated during last two decades clearly indicated that IFF approach holds high promise as an instrument to provide food security, nutritional benefits, employment and income generation to resource poor farmers. Moreover, The IFF technology compliments cropping activities of small farmers, diversifies farming activities and generate employment and income, thus leading to enhanced nutrition, social and economic uplift of the society.In this paper,current agricultural situation in Uttarakhand hills, IFF technology and its potential to sustain agriculture in hills, constraints in adopting the technology and future thrust is discussed**

***Keywords*: Integration, waste recycle, productivity, Livelihood, nutritional security, income generation.**

1. INTRODUCTION

Uttarakhand, a predominantly mountainous state ($28^0 44' - 31^0 25'$ N, $77^0 45' - 81^0 1'$ E) in northern India, spreads over a 53483 km^2 area and supports a population of 1.01 billion as per the 2011 census [1]. Out of 13 districts, nine are entirely hilly, two are entirely plains and another two represent both hilly and plains areas. Over 90 percent of the geographical area of the state falls under the mountain category. In the hill districts, most of the land area is under forest land and only 3.4 to 17.7% of the reported area is under agriculture [2]. Small and scattered villages with rugged, undulating terrain are the main features of the hill region (Fig. 1). Most of the farmers own smallland holdings (<1 ha) and land fragmentation continues with the increasing population and agriculture in the region relies on unpredictable rainfall. In the absence of irrigation facilities, farmers are forced to continue with cereals and millet based traditional cropping systems, which is not at all profitable. Unprecedented weather conditions in the region often resulted in crop failure. Furthermore, on the industrial front, the hilly area of the state has been pushed backward and there are very few employment opportunities other than farming for the increasing population. This situation forced them either to practice traditional subsistence farming or to migrate from the villages to small towns and cities in the plains to earn a livelihood [3].

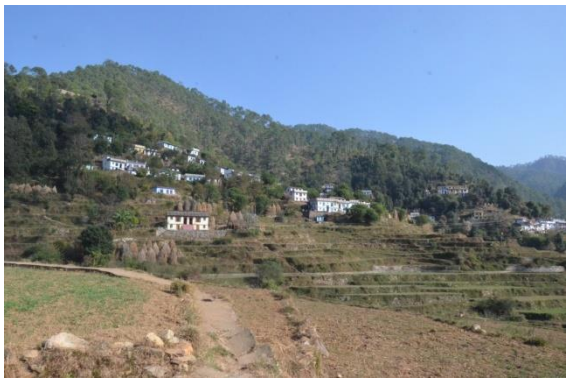

Figure 1. A panoramic view of landscape showing settlements, landholdings and forest linkage.

The farming systems in the region are livestock based and forms a spectrum of economic activities. A large livestock population makes animal husbandry an important subsidiary occupation of the farmers. It contributes to the rural economy by providing milk, meat, wool, manure etc. Animal husbandry plays a vital role in supplementing family income and generating additional gainful employment for small and marginal farmers. Livestock rearing and agricultural operations in the region are primarily carried out by female folk. However, with the steady increase in population and decreasing per capita availability of cultivated land it is difficult to produce enough food for the family [4,5,6]. Food grain production in the recent past has been constrained by declining soil fertility and unfavorable weather conditions and damaging by wild animals. Agriculture production hardly fulfills the food requirements of the people for four to six months. Under the pressure of ever-increasing population, when it is not possible to increase the cropping area, productivity than only can be increased by increasing cropping intensity through the successful implementation of available cropping patterns. Besides,vertical expansion seems to be the need of the hour to enhance farm productivity and assure a regular income for livelihood. This could be done by integrating farming systems by putting various components systematically and scientifically. Integration of various agricultural practices like fish farming, poultry faming, vegetable farming, livestock rearing mushrooms production etc. to create a self-sustaining ecosystem for sustainable production of different commodities with low investment, mitigation of risk and impact on the environment. Further, the diversified nature of this integration provides substantial employment opportunities to the farmers.

2. AGRICULTURAL SCENARIO IN MOUNTAIN REGION OF UTTARAKHAND

In the hill districts, most of the land area is under forest (64.5%) and only 3.4 to 17.7% of the reported area is under agriculture [1]. Life-supporting activities are limited, and livestock-supplemented agriculture is the mainstay of people in the sparsely populated mid-hill region (1000-1600 m), which is typically rain-fed and subsistence in nature. Small and scattered landholdings, less fertile soil, meager facilities for irrigation and the absence of advanced agricultural technologies are key factors which result in low productivity of hill agriculture[7] (Fig. 2).Agriculture is the mainstay of livelihoods for majority of households. Women play a crucial role in agriculture in the region. They are actively involved in various farming activities, ranging from the application of manure and sowing seed to weeding, harvesting and post-harvest processing. Women are also responsible for fodder, fuel wood and water. They also play a significant role in managing household and livestock production. Women are engaged in these activities on a traditional basis, merely because lack of alternative sources for employment and income generation, which in turn results in poor work efficiency, drudgery and low agricultural productivity[3,8].

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Figure 2 (A) Conventional tillage and (B) Terrace farming in hills

Most of the farmers in the region practice subsistence agriculture which involves cultivating cereals, millets and pulses using traditional methods (Fig.2). The most prevalent traditional cropping sequence in the mid hills is spring

rice-wheat-finger millet-fallow. Further, cropping intensity is very low and three crops in two years are taken. Wheat, barley, paddy, finger millet, barnyard millet and pulses like soybean and horse gram are mainly grown under rain-fed conditions in an almost fixed rotation. The yield of these crops is very low, even lower than the national average. Wild animals like monkeys, wild boars, porcupines, and bears add to hill farmers' woe. Farmers in the region are gradually quitting agriculture due to the increasing incidence of crop destruction by wild animals. The traditional farming methods being practiced is not profit oriented. Agriculture in its present form is not capable to sustain farmers' families at a satisfactory level. A high percentage of the rural population in the region is living in poverty, food insecurity and under nourished [6, 9]. Non-profitability of agriculture is the key factor behind low level of education, unemployment, malnutrition and associated health problems, particularly among rural women and children. However, the region is experiencing a shift in agricultural practices due to changing market demand and increasing loss to traditional crops by wild animals. Farmers are shifting towards cash crops such as ginger, turmeric, and medicinal herbs, to cater to the growing demand in the market. The shift towards cash crops has the potential to increase economic growth. Shortage of food and poor health, high dependency on natural resources, marginalization and limited livelihood options are some of the propulsions of mountain people's susceptibility and these are expected to be further aggravated by climatic change. All these factors force rural poor and marginal communities of this region to migrate and explore better options of livelihood earning in small towns and cities in the plains. Under these circumstances, there is an urgent need to explore multiple livelihood pathways for sustainable development. It seems imperative to improve farm productivity through diversification and supplementary economic activities through judicious use of available natural resources. Various simple, low-cost, natural resource-based environment-friendly rural technologies such as IFF are available which have great potential to increase farm production through diversification and supplement the economy of poor hill farmers.

3. INTEGRATED FISH FARMING SYSTEMS-PRINCIPLE AND PRACTICES

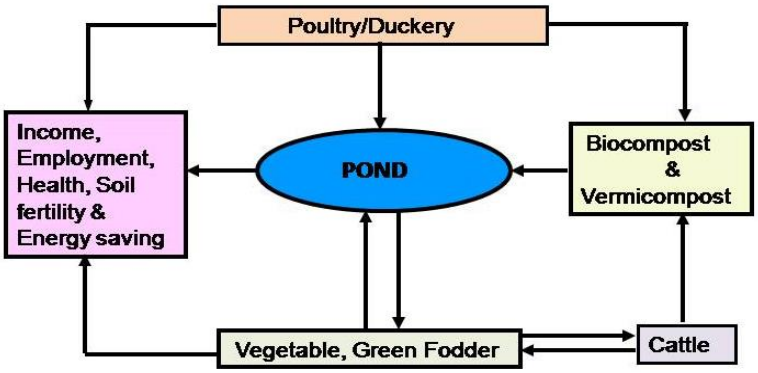

Figure 3Conceptual diagram showing resource flow in the IFF system.

Integrated Fish Farming (IFF) is a system that integrates fish, poultry, mushroom, livestock, crop production and other systems that are mutually supportive and dependent on each other. The fishery is in the center of the system (Fig 3).IFF is based on the principle of waste utilization, in which bio-product/waste from one subsystem is utilized directly or indirectly as valuable input for another subsystem. In IFF, fish are raised along with cattle, goats, poultry, ducks, pigs and crops. Sequential linkages between different farming activities are established in such a way that the waste from one biological system serves as nutrients for another biological system. Such integration thus ensures optimum utilization of available resources and results in maximum and diversified farm output making IFF a profitable venture [10]. Crop residues, and excreta of animals and birds are partially used as feed by fish and leftover act as manure to enhance the fertility of the pond thereby the growth of phytoplankton and zooplankton, natural fish food. In this system good fish production is obtained without investing in fertilizers and formulated feed. Overflow of pond water is used to irrigate vegetable fields, which results in enhanced vegetable production. After fish harvest, nutrient-rich mud from the bottom of the pond is applied into fields, which enhances soil fertility resulting in good vegetable production [6].

Integrated fish farming is a sustainable agriculture technology practiced widely in Asia and other regions of the world [11,12,13]. One of the appealing features of IFF is that it leads us to view farms in terms of interdependent components [14]. The farming subsystems, e.g., fish, crop and livestock are linked to each other in such a way that the byproducts/wastes from one sub-system become valuable inputs to another sub-system, thus ensuring total utilization of land and water resources of the farm, resulting in maximum and diversified farm output with minimum financial and labour cost. The IFF approach holds high promise as an instrument to provide food security, nutritional benefits, employment generation and providing income to resource-poor farmers [15,16,17,18,19,20,21].

Various types of integrated fish farming systems have been developed according to the topography and agro-climatic conditions, local agricultural characteristics, socio-economic conditions and traditional practices. The simultaneous culture of fish along with other agricultural practices, such as poultry farming, vegetable farming and livestock rearing is carried out to increase productivity and profitability. This practice increases the efficiency and rent ability of both livestock farming and fish culture through the profitable utilization of animal and feed waste [18, 22]. Raising pigs, ducks and chickens along with fish culture is a common technique in Asia and it has been found to be most productive [23,24]. Farmers in some countries combine fish farming with other forms of agriculture, such as geese farming, rabbits, goats, sheep and cattle rearing on a small scale to increase farm productivity. Considering the importance of IFF in the livelihood opportunities, income generation and nutritional security for the local community by improving farm productivity through diversification, a module of the integration was created and evaluated.

Integrating various components like composite carp culture, off-season vegetables, poultry farming, mushroom cultivation, green fodder production and bio-composting were demonstrated at farmers' fields. In such a system, all complimentary components are integrated and linked in such a way that each system benefits others [18,23,24,25]. The application of organic manure in the pond influences the water quality and regulates the pond productivity by stimulating plankton production [3]. Such integration generates employment and income to small farmers, but also facilitates recycling of wastes, utilization of farm and forest biomass, energy saving and helped in maintaining ecological balance [3, 23, 26].

4. THE ROLE OF IFF IN AGRICULTURAL SUSTAINABILITY IN HILLS

IFF is a new concept for mid hills of Uttarakhand, however, on socio-economic consideration this eco-friendly approach is appropriate for marginal and small hill farmers, to whom diversification becomes necessary to improve productivity of their farm. The integration increases efficiency of resource utilization and reduces the risk of crop failure through farm diversification with minimum inputs. The IFF approach hold promises to generate year-round employment opportunities for small farmers, increase family income and help to combat malnutrition by providing an additional source of animal protein and fresh vegetables. The small-scale integration is a low-cost, eco-friendly technology; even poor farmers with high working capacity can create a small-scale IFF model with locally available materials. However, the type and level of integration depends on the agro-climatic conditions, social norms, cultural values and religious factors. The market and demand for farm products should be put into consideration before establishing any integrated farming enterprise in any area.

5. DIFFERENT MODELS OF IFF IN HILLS

5.1 Poultry-Fish-Vegetable Integration

Integrated fish farming was introduced into the region with the creation of a demonstration model at Haigad (1300 m), a small village in Bageshwar district of Uttarakhand (Fig. 4).

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Figure 4(A) Feedback on IFF technology and (B) Produce from IFF in a village.

A small dig-out fishpond (100 m^2), and a low-cost poultry house was constructed from wood, stone and iron net at the dyke of the pond. Three compatible species of Chinese carps having complementary feeding habits, occupying different water columns of the pond were stocked to make better use of the available natural fish food. Fingerlings of Chinese carps (5.5-10.0 cm) *viz.*, silver carp (*Hypophthalmichthys molitrix*), grass carp *(Ctenopharyngodon idella*) and common carp (*Cyprinus carpio*) were stocked in 45:35:25 into the pond at a density of 3 fingerlings/m^2 during March, due to their known compatibility with each other, faster growth and resistance to biotic and abiotic stress. Thirty chick birds (150 gm) of a dual-purpose hybrid Kuroiler were stocked. Kuroiler is a hardy breed of chicken well suited to colder climate of hilly terrains raised for both egg and meat. The poultry birds (3000/ha) and fish species (30,000 fingerlings/ha) were stocked as reported overseas or being practiced in the country. Fish require a balanced and nutritious diet for healthy growth. In IFF, the feed for fish can be sourced from the farm itself. Everyday protein-rich chicken dropping was recycled into the pond. Due to the short digestive tract of poultry, 80% of chicken manure

represents undigested feed stuffs with as high as 20-30% being total protein. At the initial stages of stocking, polished rice bran and mustard oil cake mixed in a ratio of 2:1 were used as supplementary feed for fingerlings. Subsequently, after two months only farm waste, such as cow dung poultry droppings, grass, and vegetable wastes etc. were applied to obtain high fish production.The growth and health of fish and chick birds were monitored at regular intervals. Kuroiler birds performed promisingly under hill conditions. Besides, faster growth rates as compared to the local breed of chicken, Kuroiler exhibited a high degree of tolerance to various diseases. Similarly, Chinese carps exhibited good growth and tolerance to a range of physic-chemical properties of pond water. Fish were harvested and marketed between October and November. The weight of 10 randomly selected individuals of each species was also recorded at each harvest. The number of eggs laid, and the weight of the chicken sold was recorded precisely. Fish cum chicken is the most common type of integration being practiced by small farmers in hilly regions. Integrated fish farming reduces the cost of inputs, such as fertilizers and feed, to make it a profitable venture.

Table 1. Diverse habits and habitat of carp species

Indian carps	**Exotic carps**	**Behavior**	**Feeding habit**
Catla	Silver carp	Surface feeder	Plankton
Rohu	Grass carp	Column feeder	Vegetation
Nain	Common carp	Bottom feeder	Omnivores

The agro-climatic conditions of the region are congenial for the cultivation of off-season vegetables. Year-round vegetable cultivation on the fields (600 m^2) adjacent to the pond was practiced. This is done by using the nutrient-rich water from the fishpond to irrigate and fertilize vegetable crops. Composted household waste (vermin-compost) and FYM were applied to maintain high soil fertility. Vegetable crops were raised, harvested and sold throughout the year. The typical vegetables of the region, such as summer squash, French beans, hybrid tomato and bell pepper were grown during the summer-rainy season, while, pea, cauliflower, cabbage, radish and leafy vegetables Brassica and spinach were grown during winter, following standard package of practices. Yield and income from vegetables were precisely recorded.

5.2 DUCK-FISH- VEGETABLE INTEGRATION

Duck farming with fish culture is an economically viable and productive system for rural farmers in many Asian countries. Duck manure contains nutrients that enhance the growth of planktons, natural fish food in ponds, which can indirectly enhance fish growth. An earthen fish pond (264 m^2) and Duck house on dyke of the pond were constructed at village Manan in district Almora (Fig. 5). Fingerlings of silver carp, grass carp and common carp were released into the pond during March.Ducklings (300/ha) of the most potential egg-laying species, Khaki Campbell (*Anas platyrhynchos*) were introduced in 1 male: 5 female ratio. Throughout the year vegetable crops were grown over 600 m^2 around fishponds. At the initial stages of growth, the formulated feed was provided to the fingerlings, while after two months only farm wastes and domestic wastes were used to enhance pond fertility.

Figure 5 Duck-cum-Fish farming at village Manan

5.3 LIVESTOCK-FISH-VEGETABLE INTEGRATION

Farmers of the hill region traditionally grow vegetables for household use. Here, locally adapted genotypes of common vegetables are grown without assured irrigation. Consequently, very low yields of these vegetable crops are generally obtained, which hardly fulfill the household need. In IFF, constructed at Kalon villagea fishpond around 100 $m^2$was integrated with cattle rearing and agricultural land around 500 m^2adjacent to the fish pond was integrated for the cultivation of vegetables and cash crops (Fig. 6). Different vegetables (Table 2) were cultivated around the year in these fields. The water from the pond is used to irrigate vegetable crops and waste from the fish and poultry is also used to fertilize vegetable crops. Nutrient-rich Pond water increases soil fertility, thereby vegetables yield. Besides, vegetable waste is used as feed for grass carp and cattle. In this way farmers can get maximum benefit by less investment in a short period of time.

Table 2 Vegetables grown under mid hill conditions in Integrated Fish Farming system.

Space	Rabi (winter) Crop October - March	Kharif (summer) Crop April - September
Pond embankment and fields nearby the pond can be used for vegetable cultivation	Pea, cabbage, cauliflower, coriander, turnip, radish, spinach, fenugreek, garlic, onion and potato.	Summer squash, bottle gourd, sponge gourd, ridge guard, Bitter gourd, cucumber, pumpkin, beans, okra, bell pepper, amaranth, chilly, ginger, brinjal, tomato and turmeric.

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Figure 6 (A) Fish-Vegetable integration and (B) Fish harvesting at village Kalon

6. PRODUCTIVITY ESTIMATION AND ECONOMIC ANALYSIS OF IFF SYSTEM

Production data and economic return from different sub-systems of IFF were recorded precisely, and the economics of the system under operation was worked out. Feedback on the technological interventions, the outcome of the technology in the form of social, economic and allied benefits and acceptability were received from the beneficiaries. From an integrated system comprising a small pond (100 m^2), poultry house and vegetable fields (600 m^2) 48.7 kg and 60.3 kg fish were harvested during 2018 and 2019, respectively, corresponding to 4870 and 6030 kg/ha/yr yield. On an average of two-year, fish contributed Rs 16,350 poultry units contributed Rs53,825 while vegetables contributed Rs 12,472 towards gross income of Rs 85,103. Fish and poultry unit contributed 82.4% of gross income from IFF (Table 3).

Integrated fish farming is a great source of income and nutrition for the farmers' family. It helps to generate steady income to the farmers' families throughout the year. In addition to different farm products readily available for the family, Rs 70,000-75,000 was generated by a farmer from marketing of different products from integrated livestock-fish-vegetable farming.

Table 3 Production and income generation from a small IFF unit at Haigad

Produce	Village - Haigad			
	2018-19		2019-2020	
	Production	Income (Rs)	Production	Income (Rs)
Fish (kg)	48.7	14,610	60.3	18,090
Chicken (kg)	72	25,200	75	26,250
Eggs	2570	25,700	3050	30,500
Vegetables (kg)	1265	14,500	1392	15,256
Total income (Rs)		80,110		90,096
Annual Investment (Rs)		10,150		14,800
Nett income (Rs)		69,960		75,296

In another study, composite carp culture in a fish cum duck integrated system enables to get substantially high fish production from a medium size pond (264 m^2). The integrated system yielded 127 kg of fish corresponding to 4810 kg/ha/yr., 900 eggs and 14 kg of meat. The fish yields are like the fish yields (4323 kg/ha/year) reported under fish-duck integration in India and in Hong Kong (2750-5640 kg/ha/year). Fish yields can be enhanced through intensive feed supplementation at early stages of growth followed by the recycling of excreta and farm wastes. Fresh fish are in high demand in the region and easily sold at a premium price. Because duck eggs and meat are less

preferred in the region, these could not fetch good price at local market. Compared to fish-poultry-vegetable integration, this integration was found less profitable in the mid-hills of the state.

In the integrated livestock-fish-vegetable system at Kalon, 95.0 kg of fish from a 200 m^2 pond area were harvested in 2019 (table 4). Besides, improved varieties of vegetables cultivation have provided a substantial yield of different vegetables. Altogether, 895Kgof vegetables and 125 kg of cash crop were harvested during 2019-20. The yield of French beans (8.3-10.5 t/ha), tomato (9.5-21.1 t/ha), bell pepper (8.8-12.5 t/ha), pea (9.5-10.4 t/ha), green vegetables, turmeric and ginger were obtained at different periods of the year, assuring better returns from the farm. Vegetables harvested for household use were overlooked while estimating farm income. In addition to these components, Rs 52,800 were obtained from milk and ghee through cattle rearing in the integrated system [26]. Rearing of cattle and cultivation of vegetables using FYM and pond water for irrigation made the IFF a gainful venture.

Table 4 Mean production and income from Integrated Fish Farming at Kalon.

Produce	Production	Household consumption	Sold	Total (Rs)
Fish (kg) (200 m^2 pond)	95.0	5.0	90.0	27,000
Vegetables (kg)	895.0	275.0	620.0	8,940
Cultivation of cash crop				
Ginger (kg)	70.0	20.0	50.0	2,000
Turmeric (kg)	55.0	10.0	45.0	2,700
Dairy products				
Milk (liter)	1560.0	600.0	960.0	46,800
Clarified butter (Ghee)(kg)	25.0	15.0	10.0	6,000
A. Total income (Rs)				93,440
B. Total Expenditure (Rs)				14,900
Net Profit (Rs) = A – B				**78,540**

7. INTEGRATED FISH FARMING VERSUS TRAITIONAL FARMING SYSTEM

Fish farming has great potential of employment and income generation. Fish farming has established itself as a profit-oriented business. Various other complementary components, such as poultry farming, cattle rearing, mushroom and vegetable cultivation can be integrated with fish farming. By practicing IFF with traditional subsistence agriculture, farmers are producing fish, eggs, chicken, mushrooms and vegetables and getting nutritious food and income through the marketing of these products. In IFF, vegetables are grown in organic mode and fetch substantially higher prices. Several farmers in the hilly region of the state have managed to uplift their economic and social status by adopting IFF technology. The IFF model comprising fish-poultry-vegetables production has been an effective tool for employment and income generation in Uttarakhand hills during the last two decades.

8. ADVANTAGES OF INTEGRATED FISH FARMING

IFF is a sustainable and eco-friendly approach that combines fish farming with other interdependent components such as, vegetable farming, poultry farming and livestock rearing to increase productivity and profitability. There are several advantages of integrated fish farming:

I. Waste is efficiently utilized for fish, poultry and vegetable production, thereby helps to check environmental pollution.
II. It reduces the cost on supplementary feed as well as fertilization.
III. Integrated fish farming provides fish along with, eggs, meat, milk, milk products, vegetables, mushroom, fodder grass etc. on the farm itself, which improve the nutritional status of the household.
IV. IFF generates employment avenues and increases the economic efficiency of farming.
V. This technology has the potential to increase farm production and the socio-economic status of weaker sections of our society.

9. NUTRITIONAL BENEFITS OF INTEGRATED FISH FARMING

Though the prevalence of undernourishments in the state has been decreasing over the past few years, yet malnutrition continues to be a major issue in the region, particularly among women and children under five years of age [6, 26]. Factors that contribute to poor nutrition in the region include poverty, lack of access to healthcare, and inadequate dietary intake. The traditional diet in the region is largely based on cereals, pulses and vegetables. These may not provide the necessary nutrients for optimal growth and development. The majority of the rural population in rural areas of the state is under nourished. The contribution of pulses, cereals, vegetables, fruits, milk, milk products, egg, meat etc. in the diet of rural people has drastically gone down in the current food scenario. The nutritional status of a

farmers' family was investigated before and after the implementation of IFF model. It was reported that non-cereal food intake has substantially increased after the adoption of IFF (Table 5). The average intake of dietary energy, protein and fat by an individual which was calculated at 2144 kilo calories, 52.5 gm and 53.8 gm before the adoption of integrated fish farming, has increased by about 26%, 35% and 40%, respectively, after the adoption of IFF technology by the farmers' family (Table 6) [27].

Table 5 Monthly consumption of food commodities by a five members family

Commodity	**Approximate consumption**	
	Before	**After**
Rice (kg)	20.0	20.0
Wheat flour (kg)	20.0	20.0
Ragiatta (kg)	5.0	5.0
Pulses (kg)	3.0	5.0
Milk and Curd (liter)	35.0	65.0
Ghee and Oil (liter)	5.0	6.0
Potato (kg)	10.0	10.0
Onion (kg)	5.0	5.0
Other vegetables (kg)	20.0	30.0
Fruits (kg)	6.0	10.0
Eggs (Nos.)	30.0	125
Fish/chicken (kg)	2.5	5.0
Sugar(kg)	4.0	4.0

Source: Household survey

Table 6. Average intake of dietary energy, protein and fat per consumer/day

Commodity	**Calories (K Cal.)**		**Protein (g)**		**Fat (g)**	
	Before	**After**	**Before**	**After**	**Before**	**After**
Rice	461	461	10.0	10.0	0.7	0.7
Wheat flour	455	455	16.0	16.0	2.3	2.3
Finger millet flour	109	109	2.4	2.4	0.4	0.4
Pulses	70	117	4.9	8.2	0.2	0.4
Milk and curd	233	435	8.2	15.2	12.8	23.8
Clarified butter and vegetable oil	300	360	-	-	33.3	40.0
Potato	65	65	1.1	1.1	0.1	0.1
Onion	18	18	0.5	0.5	0.03	0.03
Other vegetables	47	70	2.7	4.0	0.3	0.4
Fruits	17.8	30.0	0.2	0.33	0.1	0.16
Eggs	40	83	3.2	6.7	3.2	6.7
Fish/chicken	18	36	3.3	6.6	0.35	0.7
Sugar	110	110	0.03	0.30	0.0	0.0
*Miscellaneous items	200	250	-	-	-	-
Total	2144	2700	52.53	71.06	53.78	75.69

- Tea, sweets, namkeen, biscuit, sauce, pickles, jam etc.

(Based on NSS Report No. 640: Nutritional intake in India 2009-2010)

10. CONSTRAINTS IN ADOPTION OF INTEGRATED FISH FARMING

Despite huge potential in the hill state, integrated fish farming could not develop as it was expected. Besides topography in which only small to medium size ponds can be created, cold climatic conditions offer a short period of favorable conditions for growth(March - November) for fish, which resulted in poor yield. Seepage in the pond is a common feature in the hills, which also discourage farmers for fish farming. In addition to the natural adversities, the main constraints in the adoption and scale-up of IFF in the hills are the timely availability of day-old chick birds and healthy fingerlings (5-10 cm) of fast-growing fish species. As most of fish hatcheries are in the Tarai region of the state, transportation of fish seed from there takes a long time and is expensive. High mortality of fingerlings often

occurs during transportation from hatcheries in plains to remote hilly regions. Besides, the unavailability and high cost of chick birds and poultry feed have also hampered the promotion of IFF in the region.

11. CONCLUSION AND RECOMMENDATIONS

Integrated fish farming is a promising approach for hilly areas that can provide diverse farm produces and additional source of income and improve productivity and sustainability. Farmers in several Asian countries including Bangladesh, China, Indonesia and Malaysia, have been practicing IFF for long time. The IFF technology has been introduced recently in the Central Himalayan region (3). An integrated Fish Farming system combining composite carp culture, poultry, dairy and vegetable farming is found most suitable and efficient farming system, improving farm productivity under rain-fed conditions of the hilly region. Replacement of traditional crops with high- value crops such as vegetables mushrooms; poultry, fishery etc. increased the productivity of small farms. IFF has the potential to be a sustainable source of income, food security and nutrition for farmers in the hilly region of the state, while also helping to promote environmental sustainability and rural development. Studies conducted in the region revealed that IFF enables the agricultural production system sustainable, profitable and productive on the long term. IFF has been gaining popularity in the hilly area of Uttarakhand in recent years. The state government has been promoting fish farming as means of generating additional income for farmers and supporting rural development.

The IFF models developed for different microclimatic regions can be refined through demonstrations based on multilevel interventions on participatory approach. The approach should be based on rational use of resources, location-specific; technically sound, which can sustain the productivity and economic ability of the systems. Undoubtedly, the IFF system enhances the net return, generates employment, conserves natural resources, reduces the cost of production and increases the income by minimizing risk. Hence, in the present scenario of agriculture in hilly areas, IFF is the only approach that can enable the farmers to be self-sufficient by producing diverse food. The IFF approach helps to conserve the resource base through the efficient recycling of residues and wastes within the system. It is expected that IFF practices will increase with time in the regions as it is eco-friendly and ensures higher returns as well as sustained production levels of fish and other components.

The integrated fish farming system can increase the efficiency of resource utilization and reduces risk through diversified farm outputs with little investment. It has great potential to generate year-round employment opportunities to resource-poor small farmers, increase family income and help to alleviate malnutrition and under nutrition by providing additional source of animal protein and fresh vegetables. The findings of the study prove that Integrated Fish Farming is more profitable and ecologically more sustainable than unitary system of farming. Further, the model is self-sustained and adds value to the traditional subsistence-based farming system. The IFF model at Basoli during 2004 is still running and fetching a substantial income to the beneficiary household. The non-recurring expenditure has reduced in successive years, while the demand and selling price of fresh fish, Kuroiler eggs and chicken has increased many fold, thus enhancing net income from the system. This approach has the potential to expand and scale up in other rural areas. Various other complementary enterprises like the cultivation of mushrooms, medicinal and aromatic plants, and fodder grass; bee- keeping etc. may be integrated with fish-poultry-vegetable cultivation to generate more income and make it more profitable.

12. FUTURE THRUST

IFF can play a vital role in the development of agriculture-based livelihood in the hills. The thrust should be focused on the following aspects:

- Ground-level information on IFF being practiced in the hill region covering size and integration of components, as well as the economics of various integrations under different microclimatic conditions should be generated to create a database.
- Development of infrastructures such as ponds, hatcheries and nurseries is essential for the growth of ecologically stable, environmentally sound and location specific low-cost sustainable IFF modules for different holding sizes. The government should take initiatives to provide financial support to the farmers to develop such systems.
- The farmers should be encouraged to cultivate different species of fish which has high demand in the market and integrate more profitable components based on farmers' choice and availability of the market.
- The farmers should be provided with training and capacity building to enhance their knowledge and skill in fish farming , poultry farming vegetables, mushroom cultivation etc.

By focusing on these aspects IFF can led to the development of a sustainable and profitable agriculture system in rain-fed areas of the Himalayan region.

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REFERENCES:

[1] Census Organization of India (2012)Uttarakhand Population Census data 2011. http //www.census 2011.co.in
[2] Anonymous (2014). Uttarakhand at a Glance (2013-14). Govt of Uttarakhand Directorate of Economics and Statics, Dehradun.
[3] Deepa Bisht (2011) Integrated fish farming for food, nutritional security and economic efficiency in mid hills of Indian Central Himalaya. Research Journal of Fisheries and Hydrobiology 6:1-6.
[4] H. C. Pokhriyal and N. S. Bisht (1988) Planning for agriculture development in the Himalayan region: An environmental approach. The Environmentalist 8(1): 47-56.
[5] Tej Pratap (2011) Hill agriculture: Challenges and opportunities. Indian J. of Agri. Econ. 66 (1): 33-52.
[6] Deepa Bisht (2021) Integrated Fish Farming for Livelihood in Mountain Region. A Technical Manual. Govind Ballabh Pant National Institute of Himalayan Environment, Kosi-Katarmal, Almora (Uttarakhand)71 pp. ISBN No. 978-93-5607-518-4
[7] R. K. Maikhuri, L. S. Rawat, V. S. Negi, V. K. Purohit, K. S. Rao and K. G. Saxena (2011) Managing natural resources through simple and appropriate technological interventions for sustainable mountain development. Current Science 100 (7): 992-997.
[8] R. Badola and S. A. Hussain (2003). Conflict in Paradise: Woman and protected areas in the Indian Himalayas. Mountain Research and Development 23: (3) 234-237.
[9] A. Dutta and K.Pant (2003) The nutritional status of indigenous people in the Garhwal Himalaya, India. Mountain Research and Development 23: 278-283.
[10] M. S. Gill, G. P. Singh, K. S. Gangwar (2009). Integrated farming system and agriculture sustainability. Indian Journal of Agronomy 54:128-139.
[11] Edwards P, Demaine H, Innes-Taylor N and Turongruang D (1996) Sustainable aquaculture for small-scale farmers: need for a balanced model. Outlook on Agriculture 25: 19-26.
[12] S. Choosakul (1999) Challenging crisis with sustainable farming. Sustainable resource management project northeast region, Mahasarakham, Thailand.
[13] L. Wenhua. and M. Qingwen (1999). Integrated farming systems: an important approach towards sustainable agriculture in China. Ambio 28: 655-662.
[14] J. P. T. Dalsgaard, L. Foot and V. Christensen (1995) Towards quantification of ecological sustainability in farming systems analysis. Ecol. Eng. 4: 181-189.
[15] S. Ayyappan, K. Kumar and J. K. Jena (1998) Integrated fish farming: practices and potentials. Fish Chimes 18: 15-18.
[16] B. K. Sharma and M. K. Das (1988) Integrated Fish-livestock-crop farming system. In: *The First Indian Fisheries Forum, Proceedings, Asian Fisheries Society, Indian Branch, Manglore*, pp. 27-30.
G. Kent (1997). Fisheries, Food security, and the poor. Food Policy 22: 393-404.
[17] G. Kent (1997) Fisheries, Food security, and the poor. Food Policy 22:393-404.
[18] Kiran Dube (1999) Integrated Fish Farming. Central Fishery Education Institute, Mumbai, India.
[19] K. Singh, J. S. Bohra, Y. Singh and J. P. Singh (2006) Development of farming system model for north-eastern plains zone of Uttar Pradesh. Indian Farming 5-11.
[20] U. U. Gabriel, O. A. Akinrotimi, D. O. ,Bekibele, P. E. Anyanwu and D. N. Onunkwo (2007) Economic benefit and ecological efficiency of integrated fish farming in Nigeria. Scientific Research and Essay 2: 302-308.
[21] S. Kumar, B. P. Bhatt, A. Dey, Shivani, U. Kumar, M. D. Idris, J. S. Mishra, and S. Kumar (2018) Integrated farming system in India: Status, scope and future prospects in changing agricultural scenario. *Indian J Agricultural Sciences* 88 (11): 1661–75.
[22] M. Vincke (1988) Developing productive systems under village conditions. In: Village Level Aquaculture Development in Asia. Eds. King, H.R. and K.H. Ibrahim, *Proc. Of the Common Wealth Consultative Workshops on Village Level Aquaculture Development in Africa, Freetown, Sierra Leone, 14-20 February 1985) Common Wealth Secretariat, London*, pp. 39-59.
[23] D. C. Little and P. Edwards (2003) Integrated livestock-fish farming system. FAO, Rome, Italy.
[24] M. Prein (2002.) Integration of aquaculture into crop-animal system in Asia. Agricultural Systems 71: 127-146.
[25] S. Melaku and P. Natarajan (2019) Status of integrated aquaculture- agriculture system in Africa. International Journal of Fisheries and Aquatic Studies 7(4): 263-269.

[26] J. Pant, H. Demaine and P. Edwards (2005) Bio-resource flow in integrated agriculture aquaculture systems in a tropical monsoonal climate: a case study in Northeast Thailand. Agricultural Systems 83:203-219.
[27] Deepa Bisht (2021) Livelihood enhancement of small farmers of Uttarakhand hills through integration of simple, cost-effective, eco-friendly rural technologies. Final Technical Report DST/WOS-B/580/2016-2021.